E&A
INST. ENT.
15 1933

CIRCULAR No. 275 APRIL 1933
UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D.C.

THE INFESTATION OF CORN EARS BY THE EUROPEAN CORN BORER, AND CRIBBED CORN AS AN AUXILIARY SOURCE OF INFESTATION

By L. H. PATCH, *associate entomologist, Division of Cereal and Forage Insects, Bureau of Entomology*

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INTRODUCTION

A varying percentage of the corn ears harvested from fields infested with the European corn borer (*Pyrausta nubilalis* Hbn.) contains hibernating borers. When these ears remain in storage in corncribs until the next summer their potential importance as a source of infestation for the following crop depends upon the number of borers present in the plants from which they were harvested. Ears harvested from heavily infested fields may constitute an important source of reinfestation, whereas ears harvested from lightly infested fields are not so important in this capacity. With these facts in mind, a study was made of the borer population of the harvested ears in relation to the density of population in the entire plants and in the fields from which they were gathered. Data were obtained, also, on the proportion of the borers, present in the ears, that succeeded in completing their development and emerged as moths the following summer in time to produce another generation of borers. The numbers of borers infesting the ears can be determined either by examining ears in the crib or by estimating the population from sample ears taken in the field immediately before the harvest. The data presented in this circular were obtained by the latter method.

Surveys have been made each year since the European corn borer was first found in the cornfields of Ohio in 1921, to determine the status of the borer in the earliest infested territory of the State. These surveys have included the examination of samples of plants to determine the percentage infested and of smaller samples to determine the numbers of borers contained in the stalks and ears, respectively, of the infested plants. The data on ear infestation were taken in the counties of northern Ohio bordering Lake Erie. Data were taken from 163 fields in 1926, from 385 in 1927, from 284 in 1928, and from 174 in 1929. In each field a sample of 500 plants was examined in obtaining the percentage of plants infested by the borer and a sample of 10 infested plants in determining the numbers of borers in the stalks and in the ears.

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RELATION OF THE INFESTATION IN CORN EARS TO THEIR MATURITY

The reliability of the estimate of the numbers of borers contained in the corn ears put into cribs depends on whether the field data indicate accurately the number of borers contained in the ears at harvest. It was at first assumed that the data taken in early September, when the ears are in the milk, was representative of the borer population in the mature ears ready for the crib, and that field data taken as early as that could be used for estimating the borer population in the cribbed corn. That it might be learned whether this was true the ears from each of the fields sampled were noted in the records as being either in the premilk, the milk, the soft dough, the hard dough, or the mature stage of development. The date of the examination was noted also.

In table 1 are given the mean percentage of infestation of the plants in the fields, the mean number of borers per infested plant, and the mean percentage of infestation of the ears taken from infested plants, for each year from 1926 to 1929, inclusive, according to the stage of maturity of the ears and the mean date of record.

TABLE 1.—*Percentage of corn ears infested by the European corn borer in northern Ohio, 1926–29, according to the stage of maturity of the ears*

Year	Stage of maturity	Mean date of record	Plants examined for—			Mean plants infested	Mean borers per infested plant	Mean infestation of ears from infested plants
			Percentage of plants infested	Borer population per infested plant	Infested ears			
			Number	*Number*	*Number*	*Percent*	*Number*	*Percent*
1926	Premilk and milk	Aug. 27	27,500	476	458	12.4	2.01	13.3
	Soft dough	Sept. 7	8,500	152	113	17.4	2.13	9.7
	Hard dough and mature	Sept. 27	45,500	850	761	24.6	2.11	3.4
1927	Premilk and milk	Sept. 11	77,000	1,301	1,239	9.1	1.47	1.7
	Soft dough	Sept. 18	48,500	840	828	10.5	1.80	2.4
	Hard dough and mature	Sept. 29	67,000	1,297	1,291	16.7	1.76	.6
1928	Premilk and milk	Sept. 10	7,000	121	110	8.7	2.07	3.6
	Soft dough	do	20,000	387	356	14.1	2.02	4.5
	Hard dough and mature	Sept. 24	115,000	2,061	1,949	16.3	1.69	1.8
1929	Premilk and milk	Sept. 5	19,000	327	293	11.9	1.71	8.7
	Soft dough	Sept. 12	18,500	365	365	16.0	1.51	5.5
	Hard dough and mature	Sept. 22	49,500	932	932	18.4	1.50	1.1
Mean	Premilk and milk	Sept. 6				10.5	1.82	6.8
	Soft dough	Sept. 12				14.5	1.87	5.5
	Hard dough and mature	Sept. 26				19.0	1.77	1.7

Table 1 shows that in each of the 4 years the mean percentage of ears infested by the borer in the last week of September was considerably less than in the last week of August or the first part of September. The mean percentage of infested ears for all 4 years decreased from 6.8 on September 6, when the ears were in the premilk or milk stage, to 1.7 on September 26, when the ears were either in the hard dough or mature stage. The decrease, for equal percentages of plants infested, would be more than that indicated in table 1 because the mean percentage of infestation of the plants was nearly twice as much in the fields examined on the mean date, September 26, as in the fields examined on September 6 and, as will be shown later, the percentage of ears infested tends to be greater rather than less in the fields having a higher percentage of the plants infested.

The decrease in the percentage of ears infested, with an advance in the date and maturity of the corn, is probably due to the fact that the borers leave the less desirable hibernating quarters in the drier ears. The percentage of the ears found infested by the borer before the last week of September does not, therefore, give a reliable estimate of the percentage of infestation of the ears at the time of harvest.

COMPARATIVE BORER POPULATIONS IN THE CORN EAR, THE PLANT, AND THE FIELD

It is to be expected that the borer populations of the corn ears will increase with an increase in borer population of the plants and of the fields from which they are harvested. Estimates of the numbers of borers in the ears harvested from fields containing infestations of different degrees would indicate the relative importance of these ears as an auxiliary source of infestation. All of the data on ear infestation taken in 1926–29, from the fields where the ears were considered mature and past the hard-dough stage, were classified according to the percentage of infestation of the fields. All of the fields having 0 to 5.4 percent of the plants infested were placed in the first class, the fields with percentages of infestation of 5.5 to 10.4 percent were placed in the second class, and the fields with higher percentages of infestation were classified similarly. The mean percentages of infestation of the fields in the different classes are given in table 2, together with the data on ear infestation and the number of borers per infested plant.

TABLE 2.—*Mature corn ears infested by the European corn borer, according to the degree of infestation of the fields in northern Ohio from 1926 to 1929, inclusive*

Class interval, percent	Mean plants infested	Mean borers per infested plant	Ears examined from infested plants	Ears infested	Borers in the infested ears	Fields examined
	Percent	*Number*	*Number*	*Number*	*Number*	*Number*
0 to 5.4	2.4	1.25	552	6	6	78
5.5 to 10.4	7.9	1.42	402	6	6	45
10.5 to 15.4	13.1	1.46	338	4	4	38
15.5 to 20.4	18.0	1.54	253	3	3	27
20.5 to 25.4	22.8	1.79	262	3	3	28
25.5 to 30.4	27.9	1.95	180	2	2	18
30.5 to 35.4	33.2	2.20	177	4	4	18
35.5 to 40.4	37.8	2.27	112	2	2	12
40.5 to 45.4	42.6	2.61	96	2	3	10
45.5 to 50.4	46.4	3.10	30	0	0	3
50.5 to 55.4	53.7	2.95	39	0	0	4
55.5 to 60.4	58.2	3.11	61	6	9	7
60.5 to 65.4	63.5	2.80	39	1	1	4
65.5 to 70.4	67.6	4.45	20	0	0	2
70.5 to 75.4	72.3	2.63	27	1	1	3
75.5 to 80.4	78.1	3.72	48	4	5	5
80.5 to 85.4	83.6	2.87	30	3	3	3
85.5 to 90.4	88.6	3.90	19	2	2	2

Before discussing the data in table 2 it is well to smooth out the interclass variability of the data by taking moving averages and to determine whether the borers moved away from the mature ears with an advance in the season to the same extent that they had moved away from the immature ears (table 1). Accordingly, the data on the infestation in the mature ears were divided into four classes, with mean dates of record of September 10, 16, and 22, and October 6

(table 3). It will be noted that the mean percentage of ears infested decreased from 7.76 on September 10 to 0.84 on October 6. The mean percentage of infestation of all the mature ears was found to be 1.82. The mean date of record was September 27. Therefore, it is estimated that if all the data on infestation had been taken on October 6, the numbers of borers in the ears would have been only 46.2 percent of the numbers shown in table 2.

TABLE 3.—*Percentage of mature corn ears infested by the European corn borer in northern Ohio, according to the date of examination during the period 1926 to 1929, inclusive*

Mean date of record	Plants examined for—			Mean plants infested	Mean borers per infested plant	Mean infestation of ears from infested plants
	Percentage of plants infested	Borer population per infested plant	Infested ears			
	Number	*Number*	*Number*	*Percent*	*Number*	*Percent*
Sept. 10	12,500	246	219	34.4	2.81	7.76
Sept. 16	12,500	202	186	20.0	1.93	3.76
Sept. 22	53,500	961	905	17.3	1.63	1.33
Oct. 6	75,500	1,606	1,424	21.5	1.65	.84

The results of smoothing the data in table 2 by taking moving averages are given in table 4. Each value in column 1, table 4, is a weighted moving average of 5 values given in column 2, table 2, the values being weighted by the product of the number of plants (500) examined per field and the number of fields enumerated in column 7, table 2. Similarly, each value in column 2, table 4, is a weighted moving average of 5 values given in column 3, table 2, the values being weighted by the product of the number of infested plants (10) dissected for borer population in each field and the number of fields.

TABLE 4.—*Estimates of the infestation of mature corn ears by the European corn borer in northern Ohio at the time of harvest (October 6) and of the percentage of the total number of borers in corn ears at that time, according to the percentage of plants infested and the corn-borer population per infested plant from 1926 to 1929, inclusive* [1]

Mean plants infested	Mean borers per infested plant	Mean borers in the ears of 100 infested plants [2]	Mean borers in the ears of any 100 plants	Mean borers in the stalks and ears of any 100 plants	Proportion of total number of borers in the ears	Estimated moths emerging from cribbed corn per acre of 9,000 plants
Percent	*Number*	*Number*	*Number*	*Number*	*Percent*	*Number*
10.0	1.43	0.53	0.05	14.3	0.35	1.4
15.9	1.58	.55	.09	25.1	.36	2.5
21.1	1.72	.58	.12	36.3	.33	3.3
26.0	1.89	.62	.16	49.1	.33	4.5
30.4	2.07	.74	.22	62.9	.35	6.1
34.7	2.25	.81	.28	78.1	.36	7.8
39.0	2.43	.87	.34	94.8	.36	9.5
45.6	2.67	1.82	.83	121.7	.68	23.2
51.5	2.86	2.15	1.11	147.3	.75	31.0
57.5	3.15	2.32	1.33	181.1	.73	37.1
61.4	3.08	2.59	1.59	189.1	.84	44.4
66.8	3.25	3.60	2.41	217.1	1.11	67.2
73.4	3.25	2.68	1.97	238.5	.83	55.0
78.0	3.45	3.35	2.61	269.1	.97	72.8

[1] The data given were computed as moving averages of 5 values from the data in table 2.

[2] The percentage of infestation of the ears harvested from infested plants is approximately equal to the mean number of borers in the ears of 100 infested plants.

The values in column 3, table 4, were calculated from the values in columns 4 and 6, table 2. Moving totals of 5 corresponding values in columns 4 and 6, table 2, were first obtained. The moving totals of column 6 were divided by the moving totals of column 4 and the quotients multiplied by 100 in order to obtain the mean numbers of borers in 100 ears harvested from infested plants. It was estimated that 95 ears were harvested from 100 plants. Therefore, the mean number of borers in the ears of 100 infested plants (column 3, table 4) was calculated by multiplying the number of borers in 100 ears from infested plants by 0.95 and by multiplying again by 0.462 to allow for the borer migration away from the mature ears prior to October 6.

The mean number of borers in the ears of any 100 plants (column 4, table 4) was calculated by dividing column 3, table 4, by 100 and multiplying the quotient by the number of infested plants out of 100 plants (column 1, table 4).

The mean number of borers in the stalks and ears of any 100 plants, column 5, table 4, was calculated by multiplying the number of infested plants per 100 plants (column 1, table 4) by column 2, table 4.

The percentages of the total number of borers in the fields that were found in the ears (column 6, table 4) were calculated by dividing column 4, table 4, by column 5, table 4.

Explanation of the method by which the figures in column 7 of table 4 were derived is given on page 7.

Supplementary estimates of the numbers of borers in the ears harvested from plants containing from 6 to 20 borers per plant are given in table 5. Each estimate is based on samples of from 150 to 375 ears harvested from a field at Sandusky, Ohio, in 1931.

TABLE 5.—*Infestation of mature corn at Sandusky, Ohio, based on plants having from 6.4 to 20.3 borers each*

[Corn planted May 8, 1931; data taken in March 1932]

Mean borers per infested plant	Mean borers in ears of 100 infested plants	Proportion of total number of borers in the ears	Estimated moths emerging from cribbed corn per acre of 9,000 plants	Mean borers per infested plant	Mean borers in ears of 100 infested plants	Proportion of total number of borers in the ears	Estimated moths emerging from cribbed corn per acre of 9,000 plants
Number	*Number*	*Percent*	*Number*	*Number*	*Number*	*Percent*	*Number*
6.4	13.4	2.09	374	15.9	28.5	1.79	795
9.6	21.2	2.21	591	20.3	42.6	2.10	1,188
12.3	22.3	1.81	622				

EMERGENCE OF MOTHS FROM CRIBBED CORN

The proportion of hibernating corn borers that complete their development in cribbed corn and emerge as moths has a bearing on the importance of corn stored in cribs as a source of reinfestation. In the fall of 1927, samples of corn ears apparently infested with the borer were placed in wire-screen sacks (18 meshes to the inch, through which the moths could not pass) among the ears in a corncrib. A sample of 298 ears was placed in the center of the crib and one of 259 ears was placed toward the outside of the crib near the slats. Both samples were covered with the ears in the crib. Another sample of 155 ears was placed in a screened box out of doors. During the sum-

mer of 1928 the sacks of ears were examined for the number of moths that had emerged. In December 1928 the ears were dissected to determine the total number of live and dead borers, respectively, contained in them. Table 6 shows that about 23 percent of the borers in the ears in the crib emerged as moths, and that about 89 percent emerged from ears that were unprotected from the rains. The period of emergence of the moths in the crib was somewhat later than normal, but early enough in the season to give rise to another generation of full-fed borers. The proportion of emerging moths that would have been able to make their way from among the ears in the crib to the outside, had they been permitted to attempt this, is not known.

TABLE 6.—*Emergence of European corn borer moths from cribbed corn, Sandusky, Ohio, 1928*

Position of ears in the crib	Total borers in ears	Borers dead on Dec. 6, 1928	Borers alive on Dec. 6, 1928	Borers emerging as moths	Period of moth emergence	Total ears in sample
	Number	*Percent*	*Percent*	*Percent*		*Number*
Center of crib	100	71.0	8.0	21.0	July 20 to Aug. 5	298
Near slats of crib	122	71.3	4.1	24.6	do	259
Outside of crib (check)	70	11.4		88.6	July 1 to July 10	155

Polivka and Herr [1] estimated that 53 percent of the borers in 600 infested ears in cribs at Oak Harbor, Ohio, became moths and 48.5 percent of the borers in 500 infested ears of cribbed corn at Bono, Ohio, reached the moth stage. Owing to the dry storage conditions in the cribs, emergence of the moths was retarded, as shown by the fact that only 31.1 percent of the moths emerged prior to August 20 and 48 percent prior to September 24. Results obtained from an experiment [2] conducted at Sandusky, Ohio, showed that 9 percent of the eggs laid on August 20 by late-emerging moths developed into mature borers in the corn plants upon which they were placed. It is possible that the 31.1 percent emergence prior to August 20, reported by Polivka and Herr, would have given rise to another generation of borers.

Moisture is apparently very important for the normal emergence of moths from corn ears, and its importance for moths emerging from stored cornstalks has been established. The corncrib in which the experiment at Sandusky was conducted was well built and had a water-tight roof. Undoubtedly corn stored in many temporary or poorly constructed farm corncribs that are open to driving rains or snows would afford excellent conditions for pupation of the corn borers and emergence of the adults.

DISCUSSION

The importance of corn stored in the crib as an auxiliary source of infestation depends upon the density of the borer population in the fields from which the ears are harvested, upon the number of borers that succeed in emerging from the ears as moths, and upon the pro-

[1] POLIVKA, J. B., and HERR, E. A. THE BEHAVIOR OF THE CORN BORER IN STORED CORN. Ohio Agr. Exp. Sta. Bimo. Bul. 138: 103–105, illus. 1929.

[2] SCOTT, L. B., and PATCH, L. H. THE SURVIVAL OF EUROPEAN CORN BORER LARVAE IN BARNS AND OTHER STORAGE PLACES. U.S. Dept. Agr. Cir. 281.

portion of the harvested and cribbed ears that are not fed to stock or otherwise disposed of before the emergence of the moths the following summer.

The estimated numbers of moths that would emerge from the cribbed corn harvested from a single acre in proportion to the percentage of infestation present are shown in table 4. While it is recognized that, in general, the quantity of ear corn remaining in cribs at the time of emergence of moths from such corn is greatly reduced, the potential emergence from the ears harvested from a unit area is given as a basis for judging the importance of the remaining ears. The values in column 7 of table 4 were calculated from those in column 4 by multiplying by 90, to place the number of borers in the ears on an acre basis, and again by 0.31, which is the estimated proportion of the borers in the ears emerging as moths prior to August 20, in time to give rise to another generation of borers.

Table 4 shows that the estimated number of moths emerging from cribbed corn harvested from an acre increased from 1.4 moths for fields with 10 percent of the plants infested to 72.8 moths for fields with 78 percent of the plants infested. Coincident with the increase in the percentage of infestation, the number of borers per infested plant increased from approximately 1.4 to 3.5. On referring to the data from the single field at Sandusky (table 5), it is noted that the estimated number of moths emerging from the ear corn from an acre increased from 374 moths to 1,188 moths as the mean number of borers in each plant in the field increased from 6.4 to 20.3.

The percentage of the total number of borers in the cornfields that hibernate in the harvested ears is low. By referring to table 4, columns 5 and 6, it is estimated that an average of 0.35 percent of the borers are in the ears harvested from fields that have populations up to 1 borer per plant, and that an average of 0.84 percent are in the ears from fields having borer densities from 1 to 2.7 borers per plant. Also by referring to table 5 it is seen that an average of 2 percent are in the ears from fields having borer densities of from 6 to 20 borers per plant.

The estimates regarding the borer population in the ears of cribbed corn are averages of the data taken over a period of 4 years. The estimates are subject to yearly variations, probably largely because in some years the corn ears are in a more susceptible stage of maturity relative to the development of the corn borer. The percentage of infestation in the ears of the hard dough and mature stages in 1928 was three times that in 1927 (table 1). The mean date of record and the level of borer population in the fields were approximately the same for both years. The percentage of infestation in the ears in the hard dough and mature stages in 1926 was approximately five times that of 1927 or twice the average population of the 4 years.

SUMMARY

Estimates were made of the population of the European corn borer in the ear corn harvested from fields having different densities of borer populations in the counties of northern Ohio from 1926 to 1929. These indicate that less than 1 percent of the total borer population hibernates in the ears harvested from fields that have populations as high as 2.7 borers per plant, and that less than 31 moths would emerge from the cribbed corn harvested from an acre in cornfields that have

50 percent of their plants infested by the corn borer and having population densities up to 1.4 borers per plant. The estimated number of moths per acre, emerging from the cribbed corn harvested from fields 78 percent infested and 2.7 borers per plant is 72.8. Based upon the observations reported in this circular, a range of from 374 to 1,188 moths may emerge from an acre yield of ears from plants containing 6.4 to 20.3 borers per plant. The foregoing estimates may be reduced two thirds, or may be doubled, by seasonal fluctuations in the proportion of the total borer population per field contained in the ears placed in corncribs.

The small numbers of moths emerging from stored ear corn is accounted for by the extensive migration of the borers from the ears before the harvest, and by the high mortality of the hibernating borers in the cribbed corn.

U. S. GOVERNMENT PRINTING OFFICE: 1933

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